LABORATORY RESULTS ON AMMONIA REMOVAL FROM FLY ASH USING AN ACOUSTICALLY ENHANCED FLUIDIZED BED

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THE PROBLEM

- SCR and SNCR NO_x Control Processes

  and

  FGC for Improved Electrostatic Precipitator Operation

- Inject NH_3 or Urea into Boiler

  $NH_3 + SO_3 + H_2O \rightarrow NH_4 HSO_4$

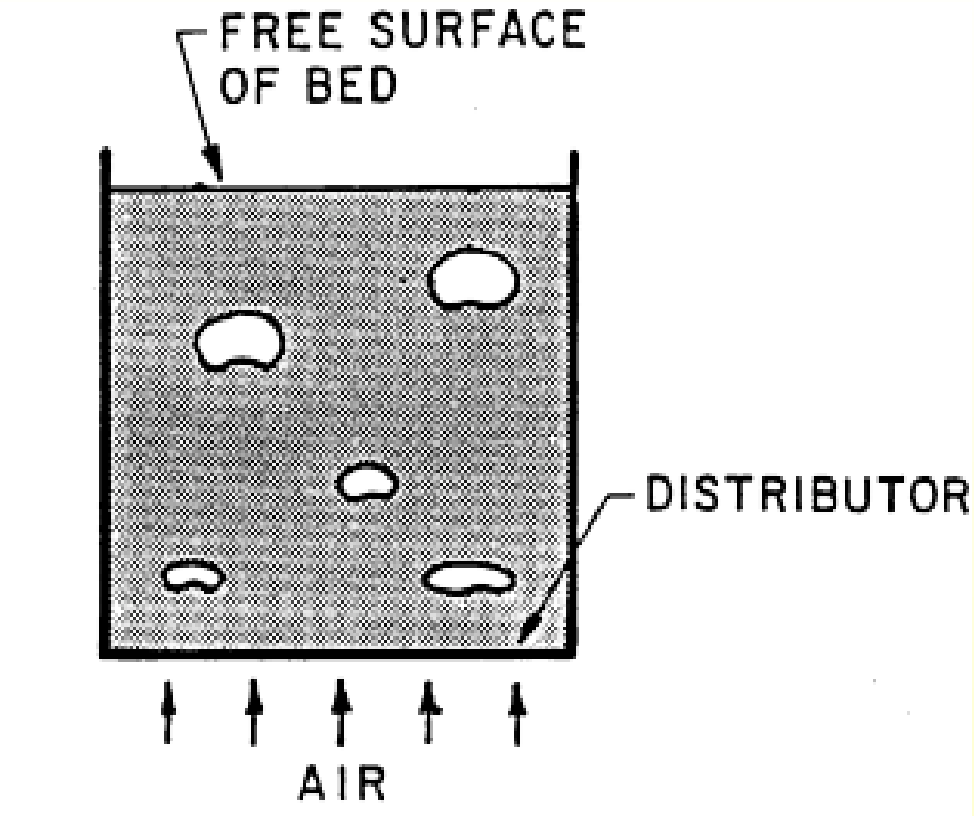
  $(NH_4)_2 SO_4$

- NH_3 Concentrations on Ash Can Exceed 1000 ppm

- Potential:
  - Health Risk to Workers
  - Groundwater Contamination from Ponded Ash

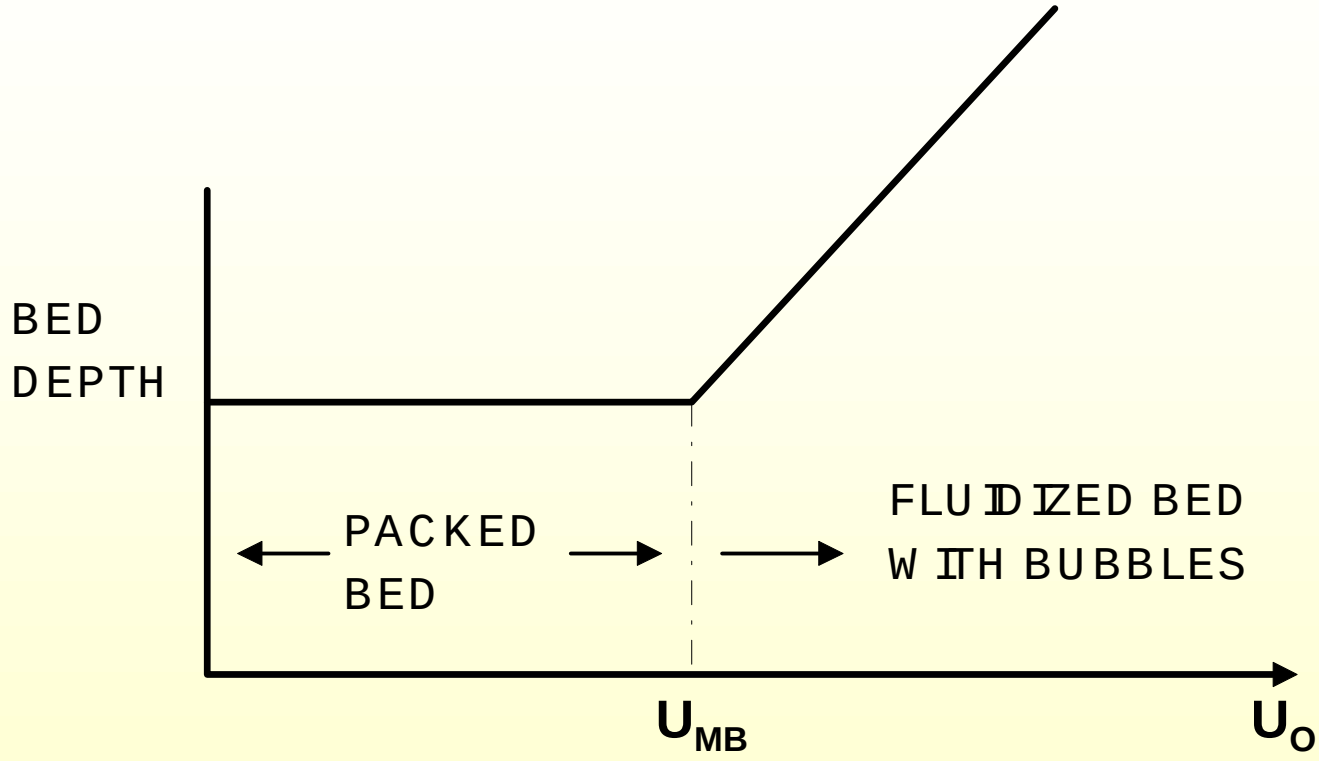
APPROACH

- Process Ash Dry
- Heat It In Fluidized Bed
- Drive Off NH_3



Sketch of Bubbling Fluidized Bed

FLUIDIZED BED TERMINOLOGY



U_O - Superficial Gas Velocity

U_{MB} - Minimum Bubbling Velocity

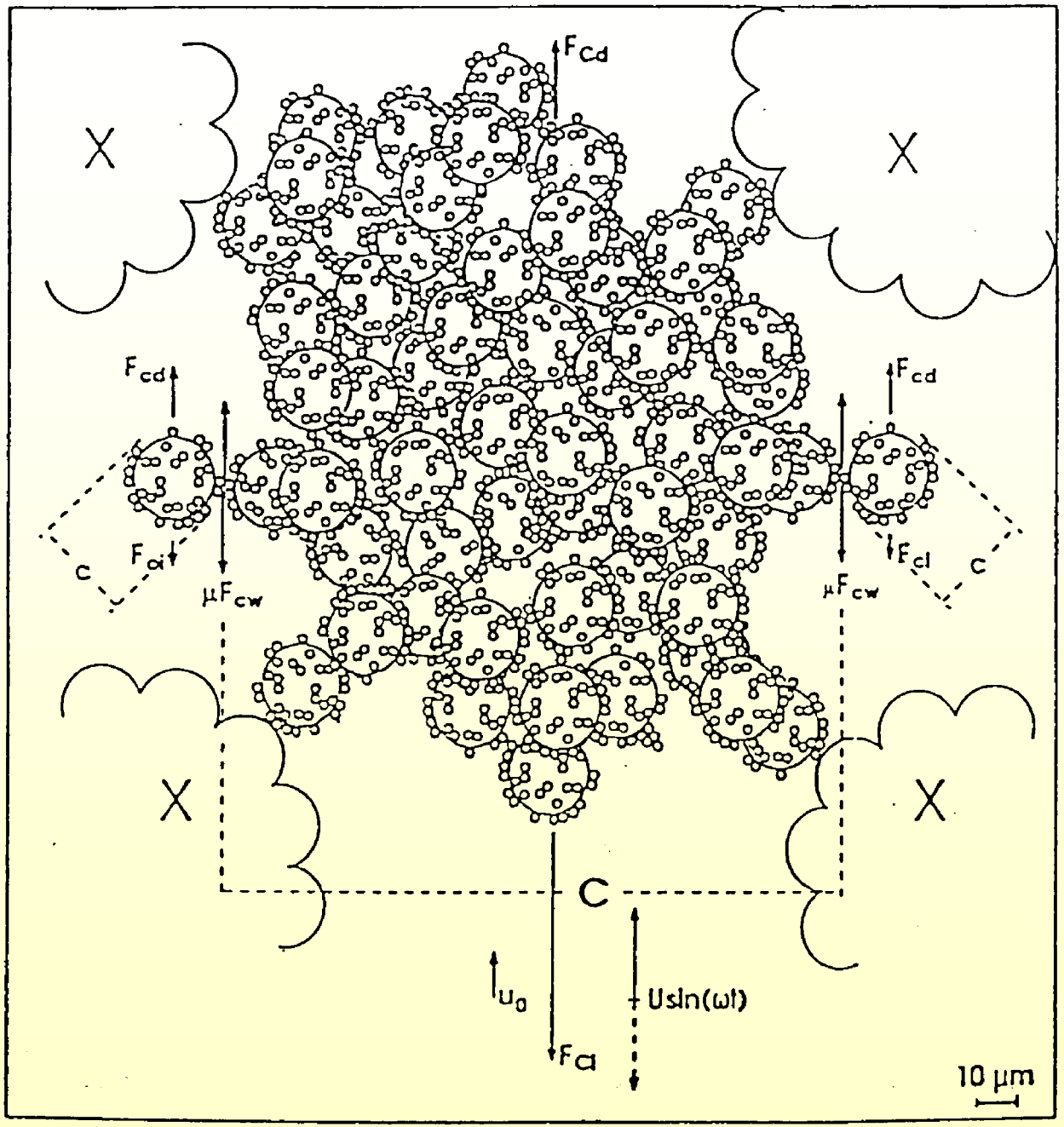
$U_O - U_{MB}$ - Excess Gas Velocity

WHY USE FLUIDIZED BED FOR NH_3 REMOVAL?

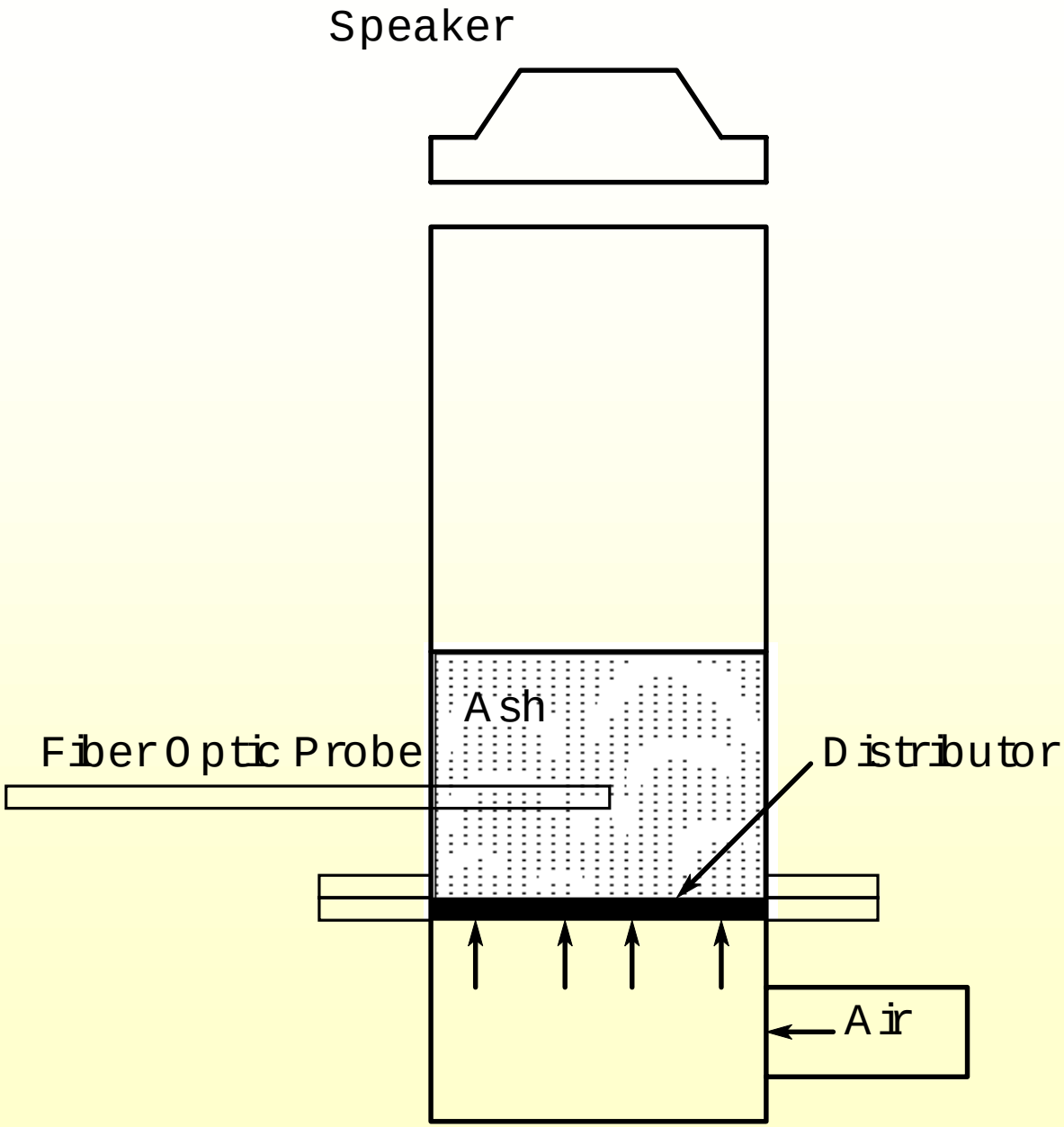
- Dry Process
- Simple – No Moving Parts
- Good Gas- Solids Contacting
- Good Tube-To-Bed Heat Transfer
  - – Low Capital Costs
  - – Low Operating Costs
- Low Fluidization Velocities $\rightarrow$ Low Air Flow Rates
  - – Lowers Cost of Off-Gas Treatment for Removing NH_3 and Entrained Ash

SOME FLY ASHES ARE DIFFICULT TO FLUIDIZE

- Fine Particles
- Van der Waals Forces – Cohesive
- Form Large Clusters of Particles in Bed
- Get Spouting or Channeling Instead of Regular Bubbling

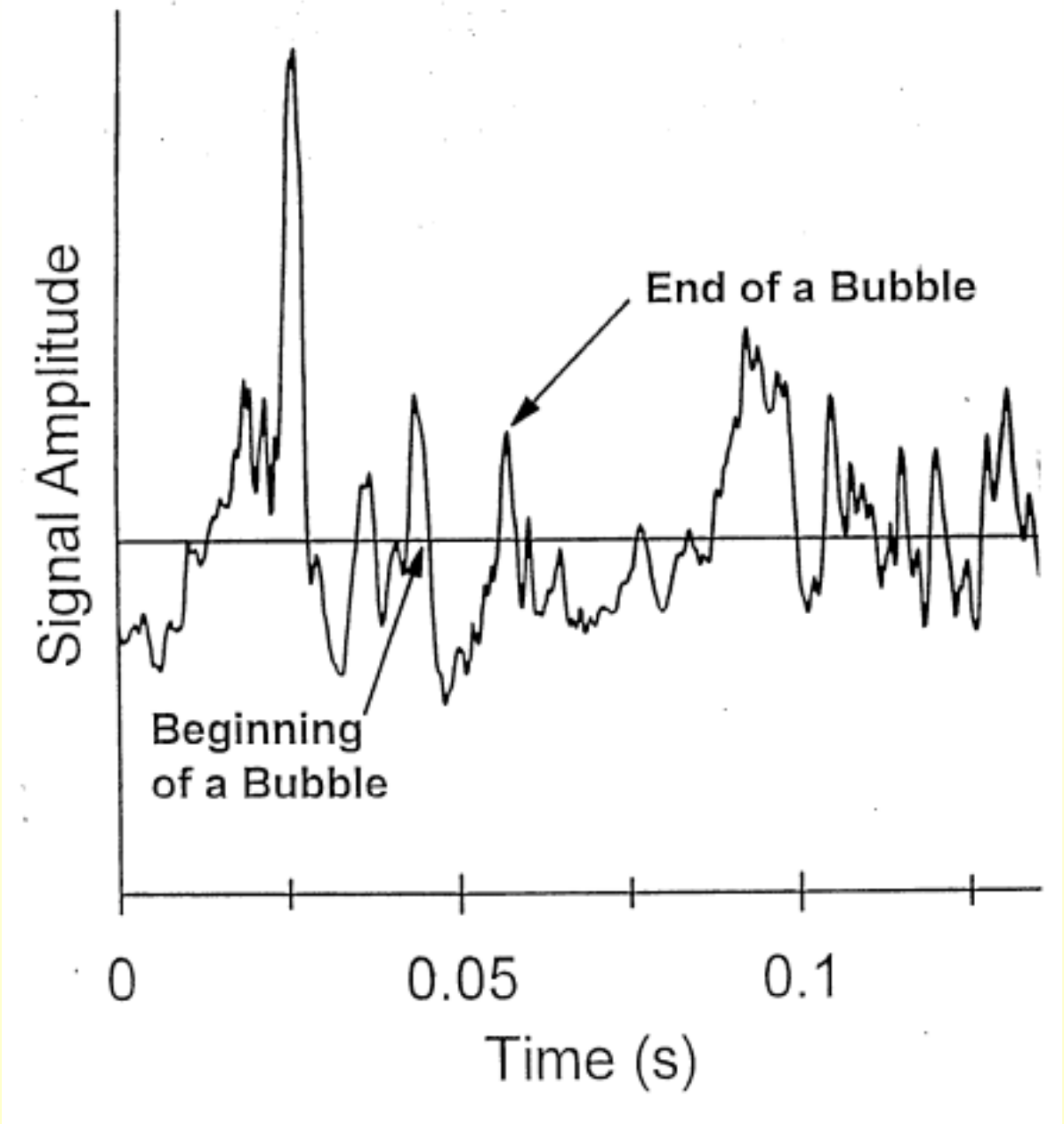

X
X
F_{cd}
F_{cd}
F_{cd}
F_{ci}
F_{ci}
C
C
μF_{cw}
μF_{cw}
X
X
C
u_0
$+ U\sin(\omega t)$
F_{ci}
10 µm

USE ACOUSTICS TO IMPROVE FLUIDIZATION

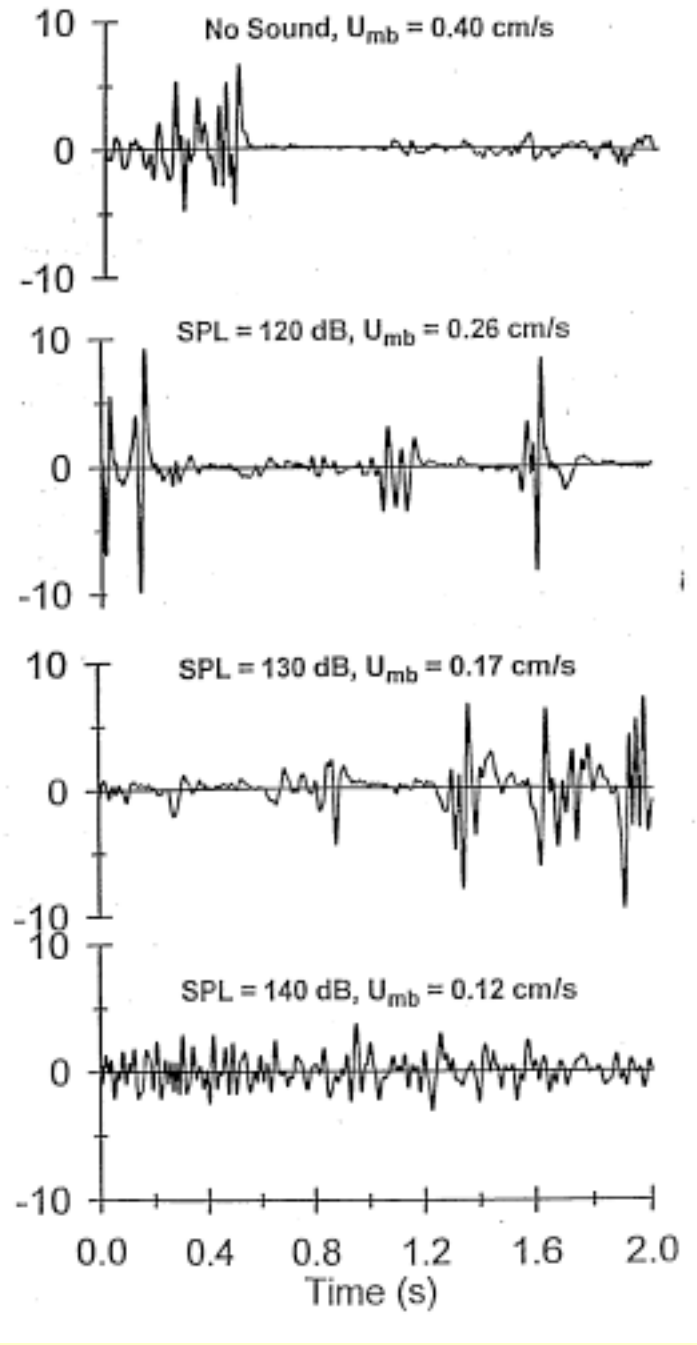

Speaker
Ash
Fiber Optic Probe
Distributor
Air

OPTICAL FIBER PROBE

- 8 mm Tube with Two Fibers Located at Inside Wall of Bed 2.5 cm above Distributor
- Used to Measure Bubbling Behavior


Signal Amplitude
End of a Bubble
Beginning
of a Bubble
0
0.05
0.1
Time (s)

Signals from Fiber Optic Probe [$U_0 - U_{MB} = 0.4$ cm/s]



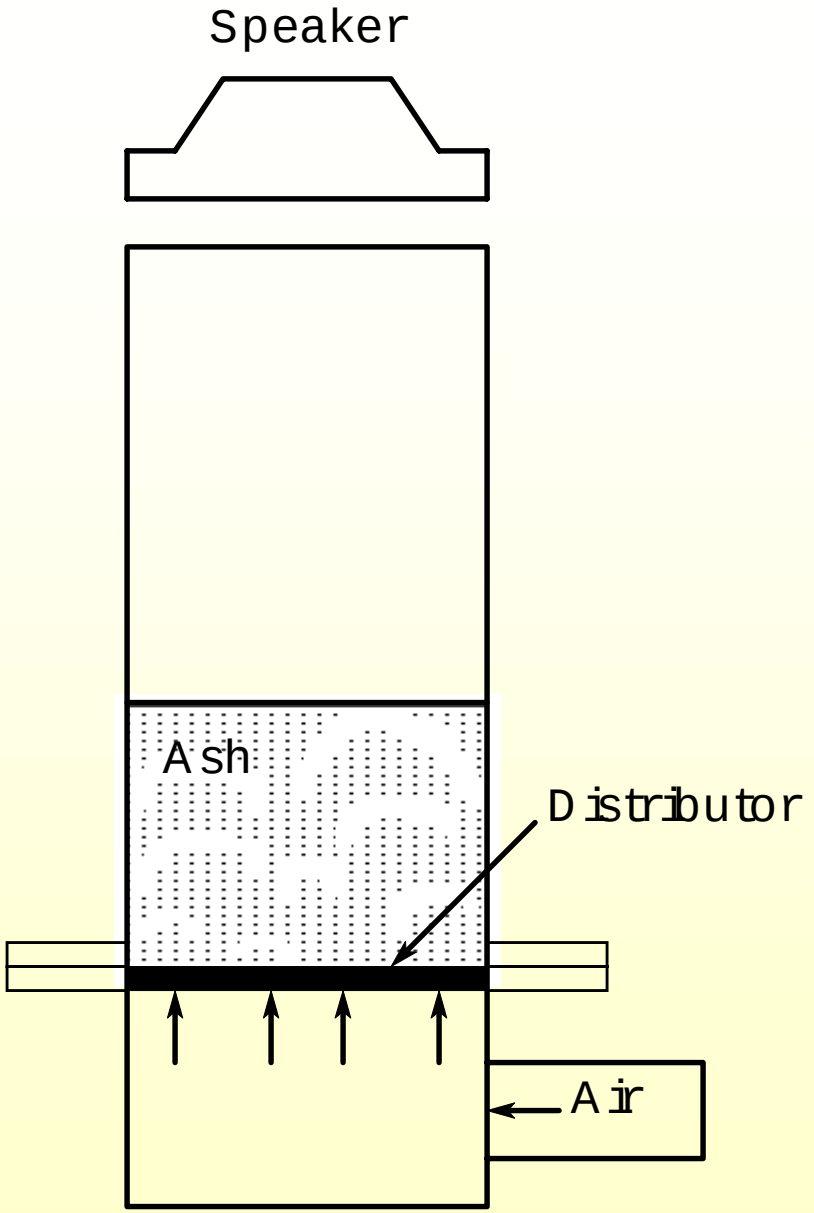
FLUIDIZATION PROPERTIES OF DIFFERENT FLY ASHES

Sample Name	LOI %	Without Sound		With Sound (140 dB)	
		U_{mb} cm/s	$U_o - U_{mb} = 0.4$ f_b (Hz)	U_{mb} cm/s	$U_o - U_{mb} = 0.4$ f_b (Hz)
A	2.7			0.12	16.
B	6.7			0.17	9.7
C	13.	0.40	15.	0.12	19.
D	2.8	0.49	2.5	0.10	21.
E	5.5			0.12	20.
F	5.3			0.12	6.9
G	5.2			0.12	16.
H	7.7			0.12	5.6
I	62.	0.76	*	0.22	*
J	16.	0.31	1.7	0.12	9.9

*The fiber optic probe was unable to measure the bubbles because not enough light was reflected from the particles. This is due to the very high carbon content.

HIGH INTENSITY SOUND

- Reduces U_{MB}
- Improves Consistency of Bubbling
- Increases Average Bubble Frequency

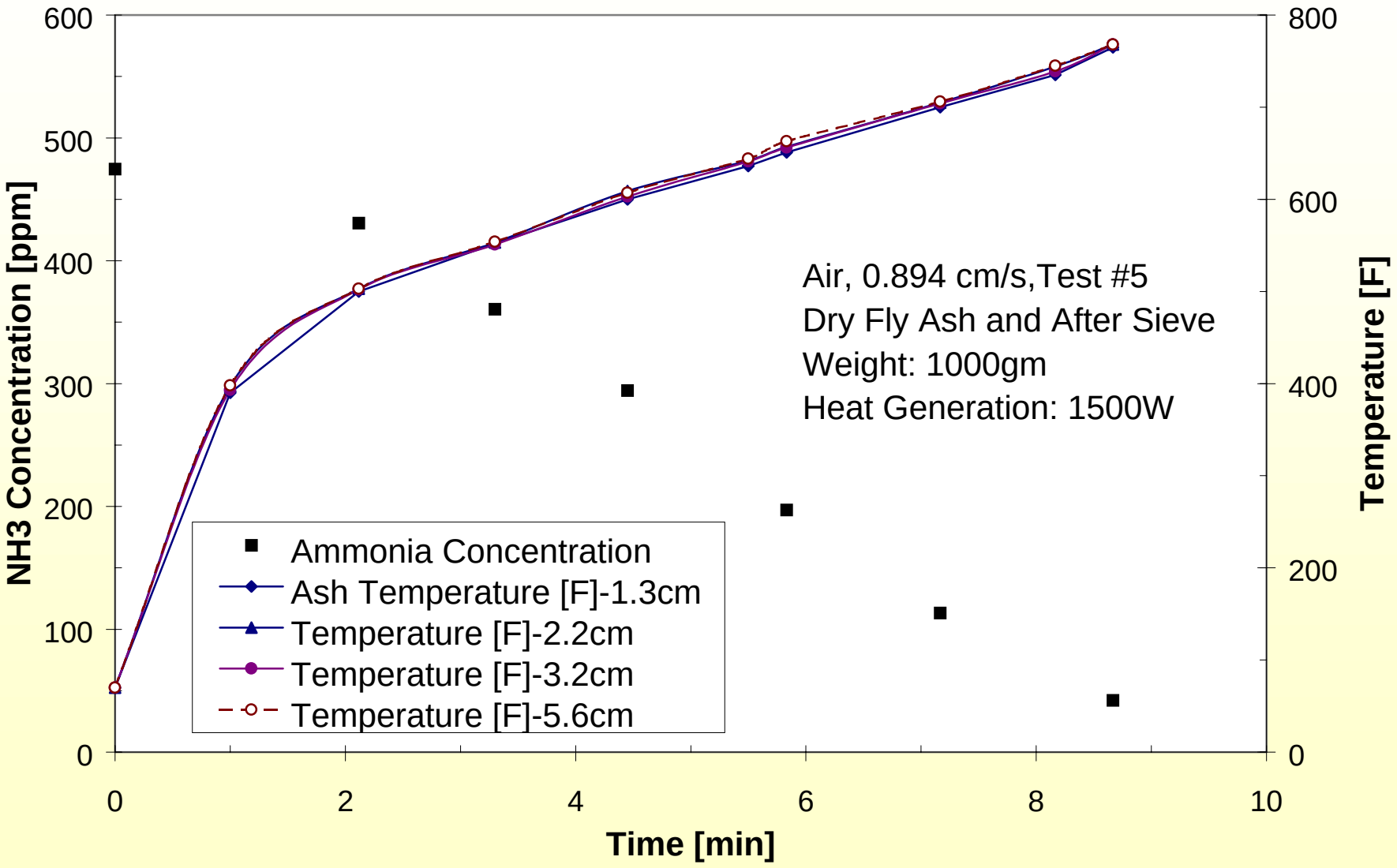


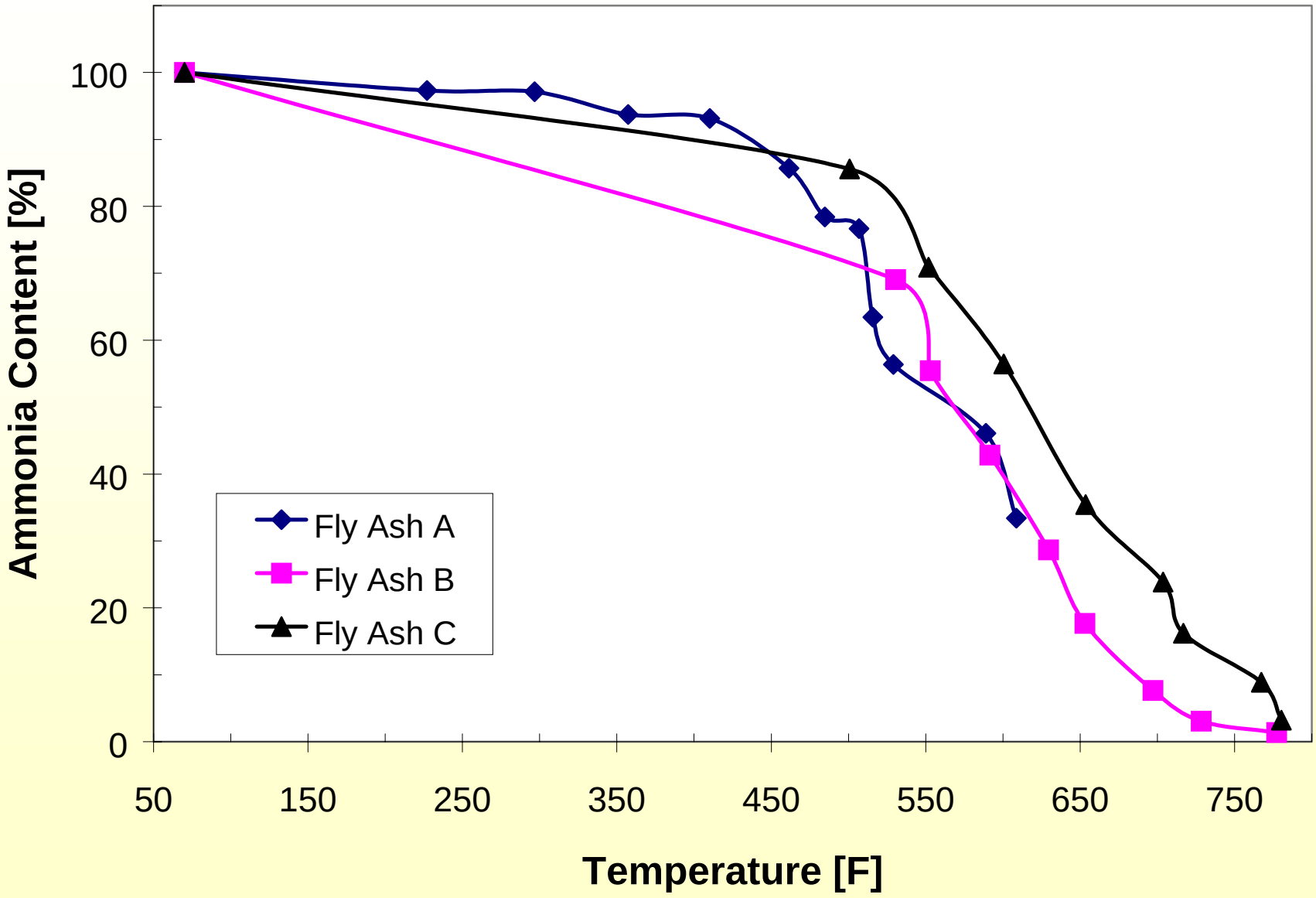
Laboratory Batch Fluidized Bed

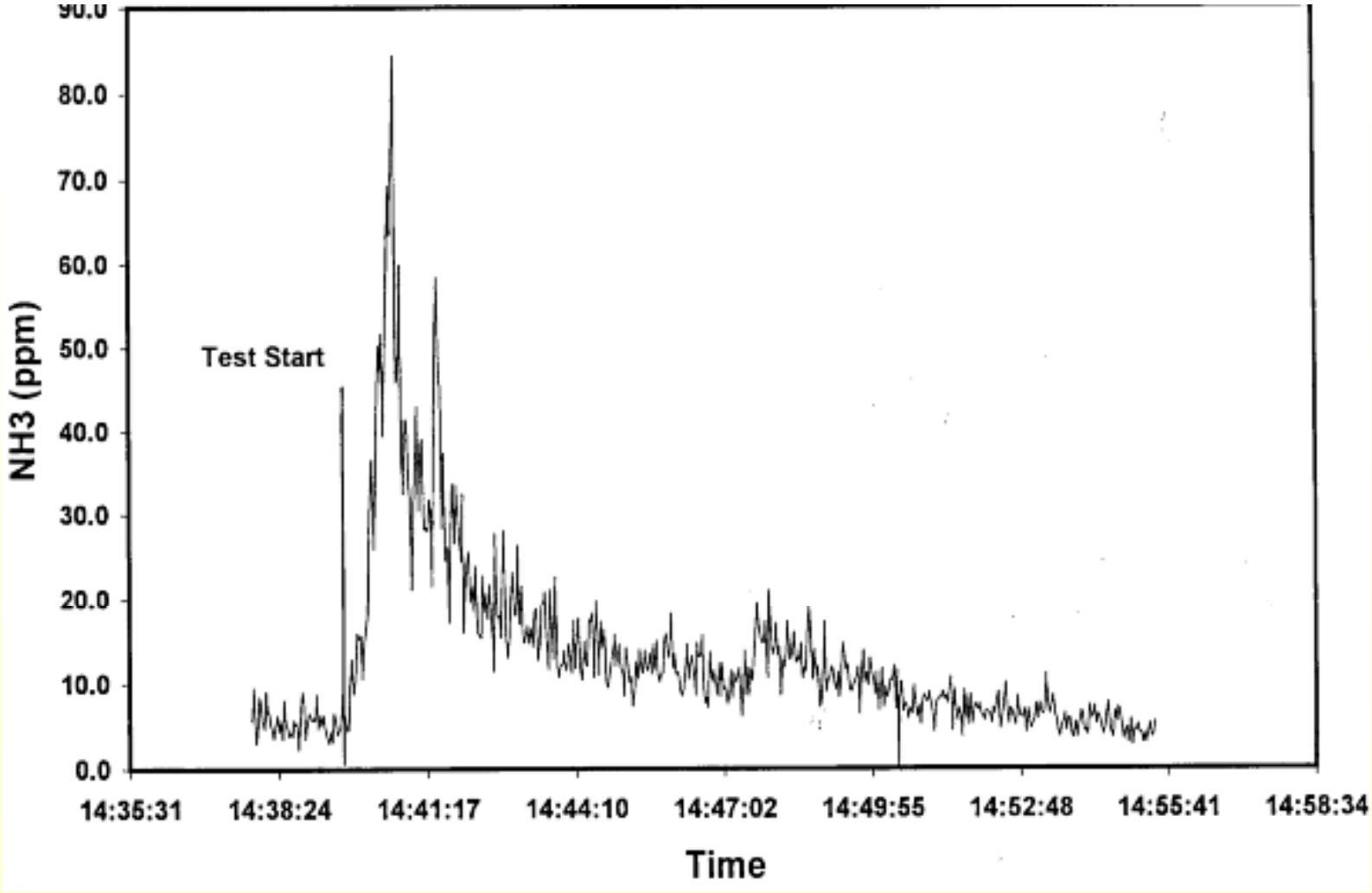
BATCH BED EXPERIMENTS

- Electrical Heating Elements Immersed in Bed
- Load in Cold Ash
- Fluidize and Heat Ash
- Remove Small Samples of Ash as Ash Heats Up
- Analyze for NH_3 Content

FLY ASH - AMMONIA SEPARATION




Ammonia Content [%]
100
80
60
40
20
0
50
150
250
350
450
550
650
750
Temperature [F]
Fly Ash A
Fly Ash B
Fly Ash C



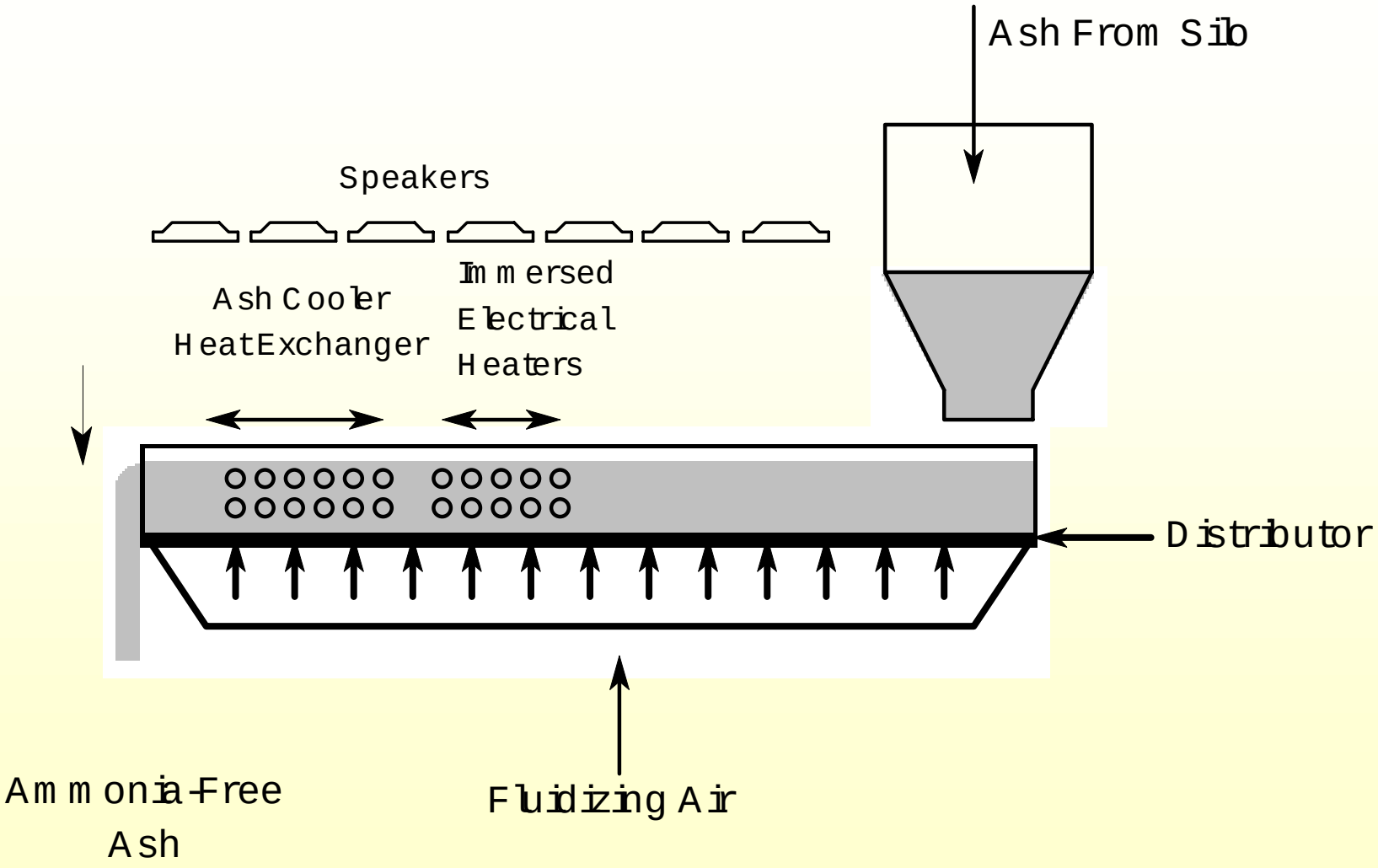
Ammonia Signal From UV Spectrometer During Ammonium Decomposition Test

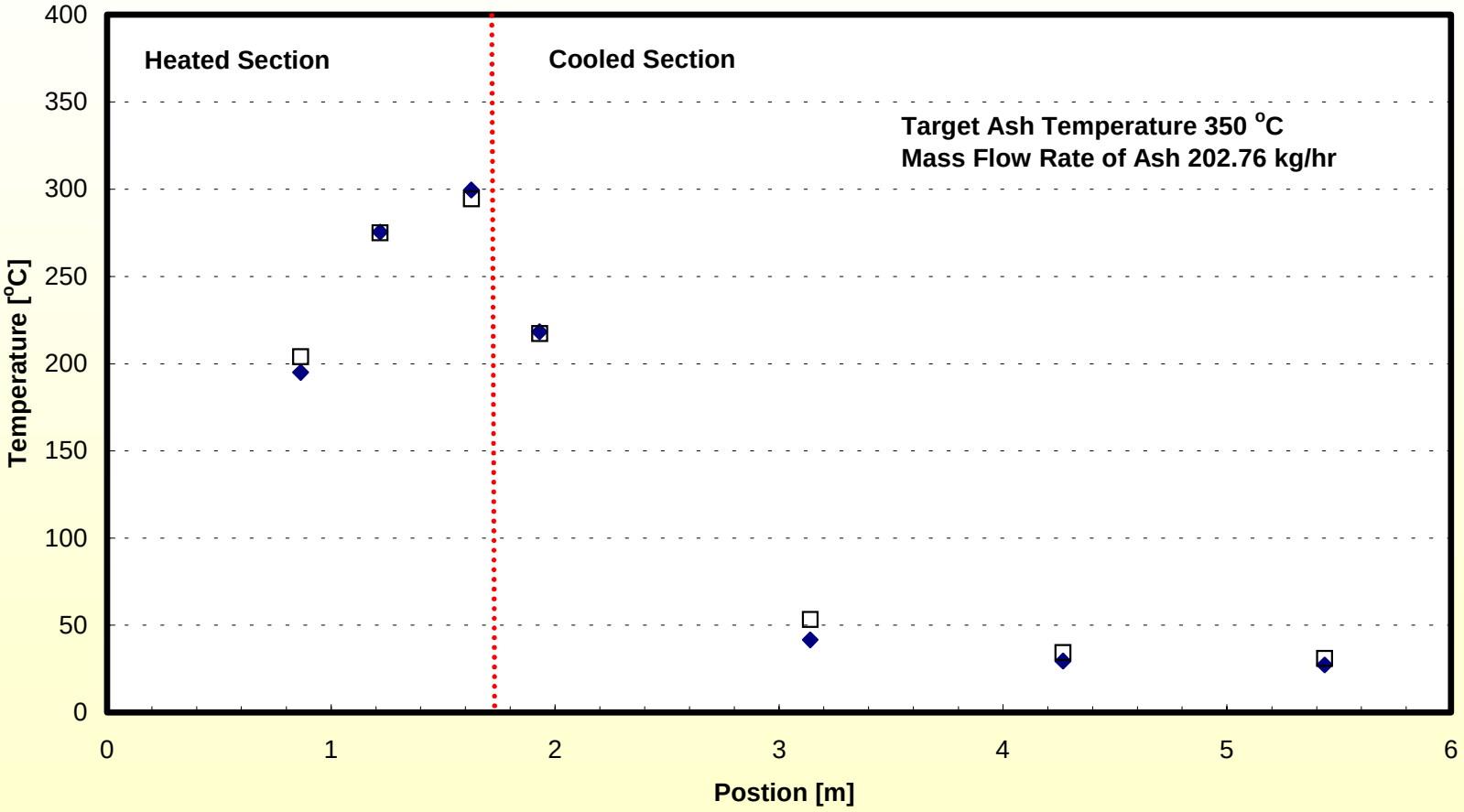
CONTINUOUSLY OPERATING SYSTEM

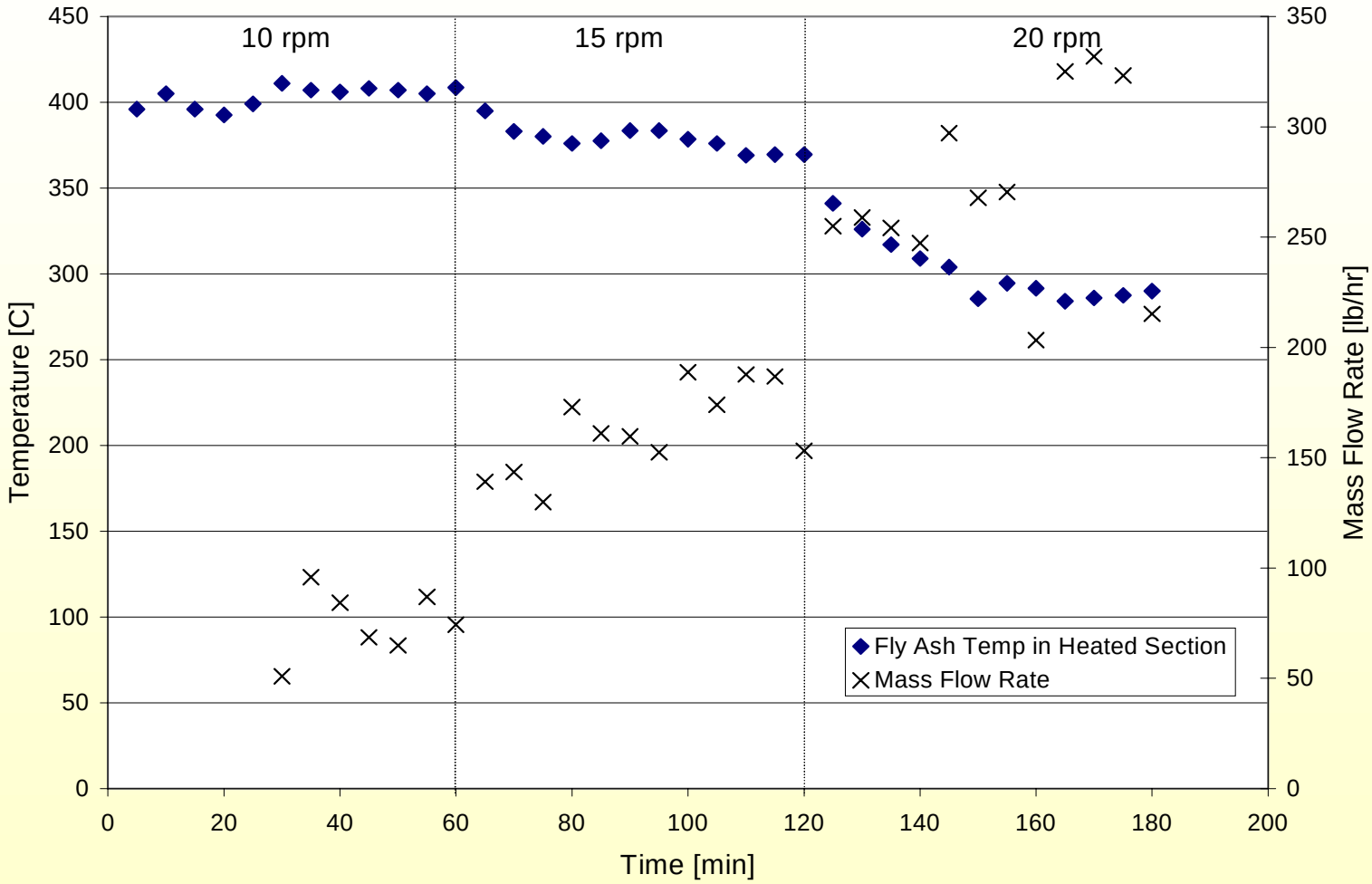
Laboratory System

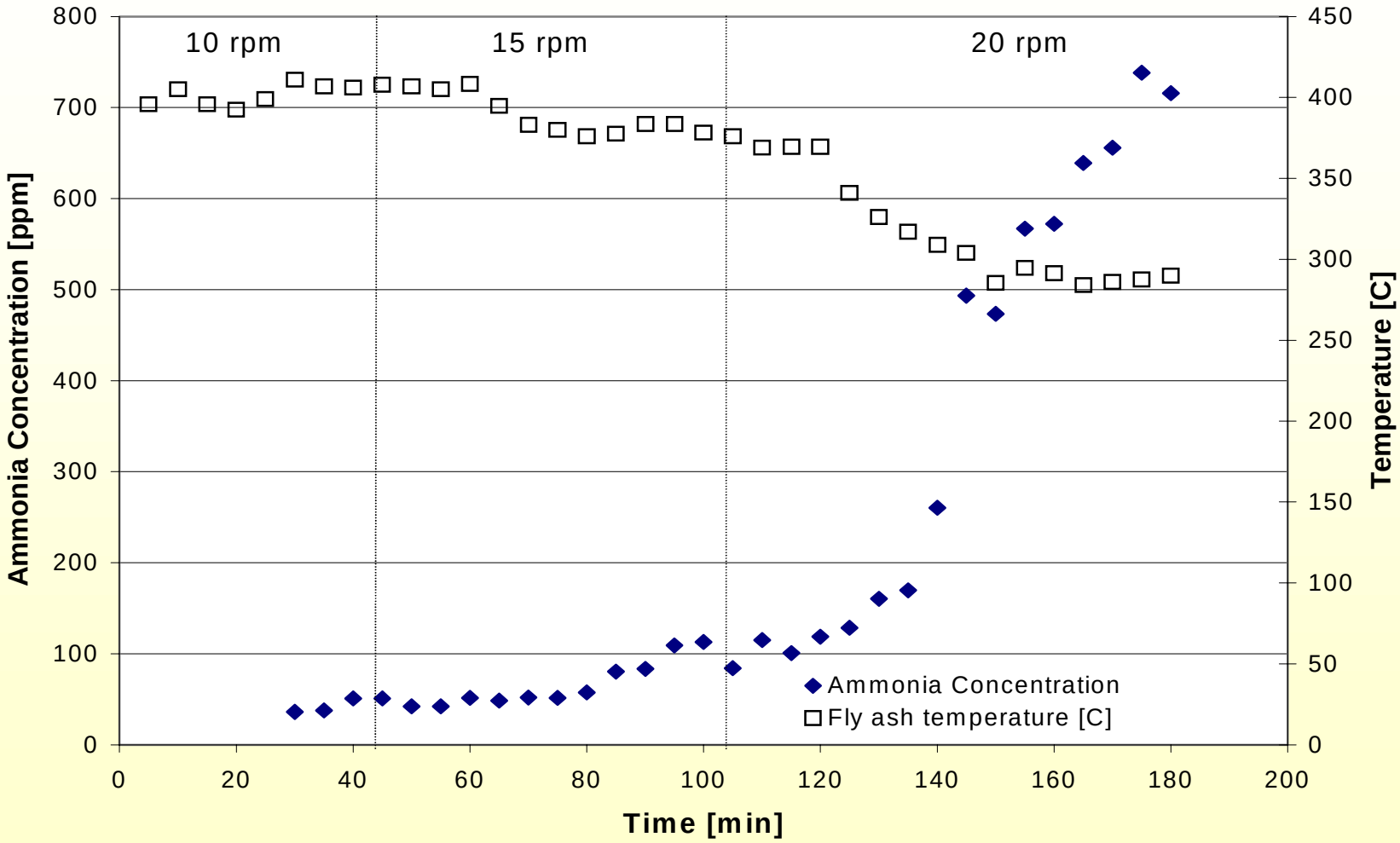
6” wide x 20 ft long

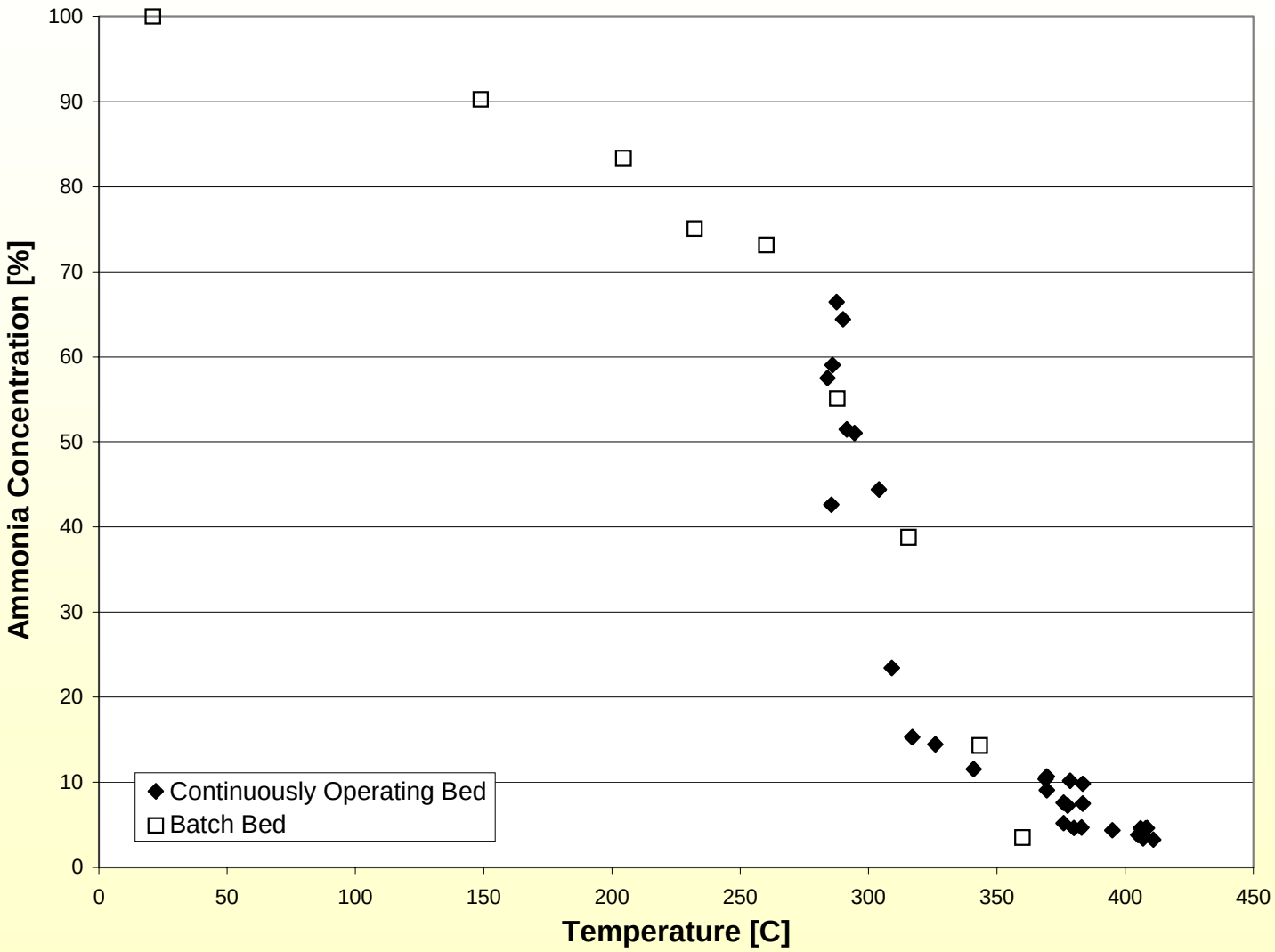
Up to 500 lb/hr


Ash From Silo
Speakers
Ash Cooler
Heat Exchanger
Immersed
Electrical
Heaters
Distributor
Ammonia-Free
Ash
Fluidizing Air

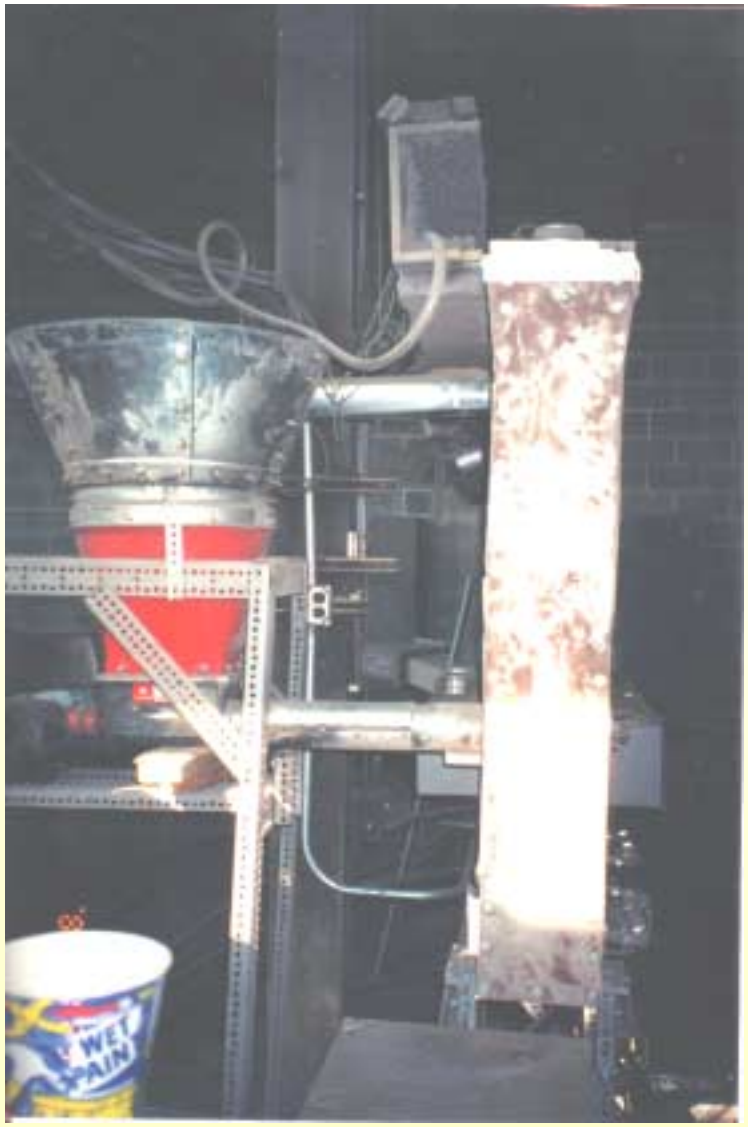

Heated Section
Cooled Section
Target Ash Temperature 350 °C
Mass Flow Rate of Ash 202.76 kg/hr
Temperature [°C]
Postion [m]
400
350
300
250
200
150
100
50
0
0
1
2
3
4
5
6


10 rpm
15 rpm
20 rpm
Temperature [C]
Mass Flow Rate [lb/hr]
Time [min]
Fly Ash Temp in Heated Section
Mass Flow Rate
0
50
100
150
200
250
300
350
400
450
0
20
40
60
80
100
120
140
160
180
200


10 rpm
15 rpm
20 rpm
Ammonia Concentration [ppm]
Temperature [C]
Time [min]
Ammonia Concentration
Fly ash temperature [C]
0
100
200
300
400
500
600
700
800
0
50
100
150
200
250
300
350
400
450
0
20
40
60
80
100
120
140
160
180
200


Ammonia Concentration [%]
100
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
450
Temperature [C]
Continuously Operating Bed
Batch Bed


'07 9 23



ENERGY COSTS

- Ash Fed to Bed at 275 ^{o}F
- Heated Electrically → 4 ¢ / kWh
- ~ $ 2.50 / ton Ash for Energy Costs

OTHER HEATING OPTIONS

- Burn Natural Gas
- Use Economizer Flue Gas

WHAT'S NEXT?

- Test Some Other Ash Samples
- Test at a Power Plant
- Develop Commercial Scale Design

SPONSORS

- Cinergy Corporation
- Ontario Power Generation
- Constellation Energy
- First Energy